Analysis of Excess Flying Time in the National Airspace System

12 March 2003

George H. Solomos

(Michelle Blucher, Jim DeArmon, Gerry Dorfman, Ho Yi)

Purpose of this Project

- **Working with the Federal Aviation Administration's (FAA) Free Flight Program Office, the Center for Advanced Aviation System Development (CAASD) has been tasked with exploring the potential benefits available from future enhancements**
  - **FAA Point of Contact: Dave Knorr**
- **Having a better understanding of where inefficiencies may be taking place, and to what extent, is important for many reasons**
  - **Control Expectations: how large of an efficiency gain is possible?**
  - **Determine Best Location: where are the efficiency gains needed?**
  - **Decide Best Time: when will enhancements be most needed?**
  - **Gaining Perspective: are benefit(s) claimed by various programs reasonable and achievable?**
- **This task has begun to answer some of these questions**

Project Scope

- **This effort has focused on estimating the extent that flights take longer in the air than some unimpeded time (i.e., excess flying time)**
  - **This is known as the "pool of benefits": how much efficiency can be gained in *today's* system?**
  - **It does not focus on other areas where benefits may be gained (e.g., fuel burn savings, workload savings, etc.)**
- **This analysis attempts to adjust for the effects of wind on flight performance**
  - **Flight times are approximated by taking the actual flight time of each flight and adjusting it by the "wind effect"**
- **The study is based upon an analysis of "good weather" days**
  - **How much benefit may be possible when weather is not a factor (or is at least a minimal influence)?**

Working Community Ideas: Complementing Existing Work

- **Work in this area (pool of benefits) has been going on for some time**
  - ***Distance* based analyses performed in the past (and current)**
    - **For example: differences between filed and flown distance, flown and great circle, etc.**
  - ***Time* based analyses have also been performed**
    - **For example: modeling and simulation of wind optimal routing versus as flown, as filed, etc.**
- **OEP Office has suggested use of "Metro Pairs" for analysis**
  - **We expanded idea into airport groupings to apply NAS-wide**
- **ATA/ASC (Barry McCoy) has suggested a technique for adjusting for winds**
  - **We applied this methodology across large amount of data on airport groupings for a NAS-wide result**
- **ASC (Capacity Office) using 100 to 200 nmi for en route analysis**
  - **Focus of initial study 40 to 40 and 10 to 10; added 100 to 100**

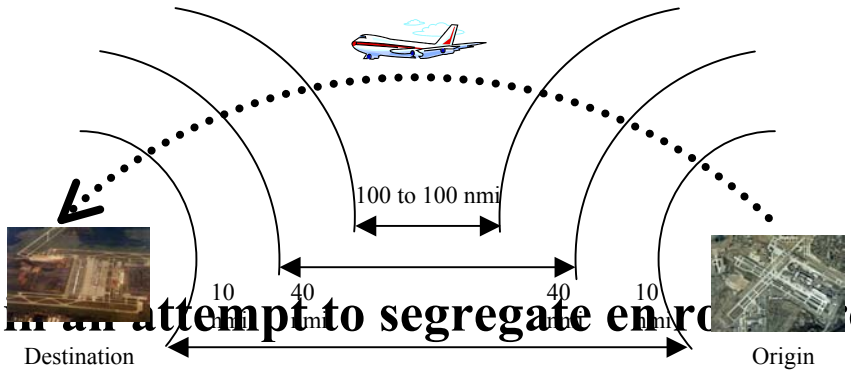
Approach

Time Frame of Interest

- Time frame studied is January to August in 2001 & 2002
  - Wanted to know impact of reduced traffic levels, 2002 vs. 2001
  - Wanted to avoid first several months of schedule changes following September 11, 2001
  - Allows comparable seasons
- Selected fifteen days from each of 2001 and 2002 as population of 30 good weather days
  - Selected days for study by ranking each day based upon a composite score combining percent cancellations, diversions, and flights with departure delay>30 minutes
  - Data source for ranking: ASQP data
- Selected one "bad weather" day for comparison
  - Much more detailed analysis is needed for bad weather conditions

Analysis of Flight Segments

- **Analysis was designed to examine flying times for three segments of flight**
  - **From 10 nmi from the origin to 10 nmi from the destination***
  - **And from 40 nmi to 40 nmi and 100 nmi to 100 nmi****



- **This was done in an attempt to segregate en route from terminal effects**
  - **Just a starting point: difficult to do without knowing where terminal restrictions have an influence on the en route**

* **Hereafter referred to as "10/10 dataset"**

** **Hereafter referred to as "40/40 dataset" & "100/100 dataset"**

Determining Excess Flight Times: The "Pool"

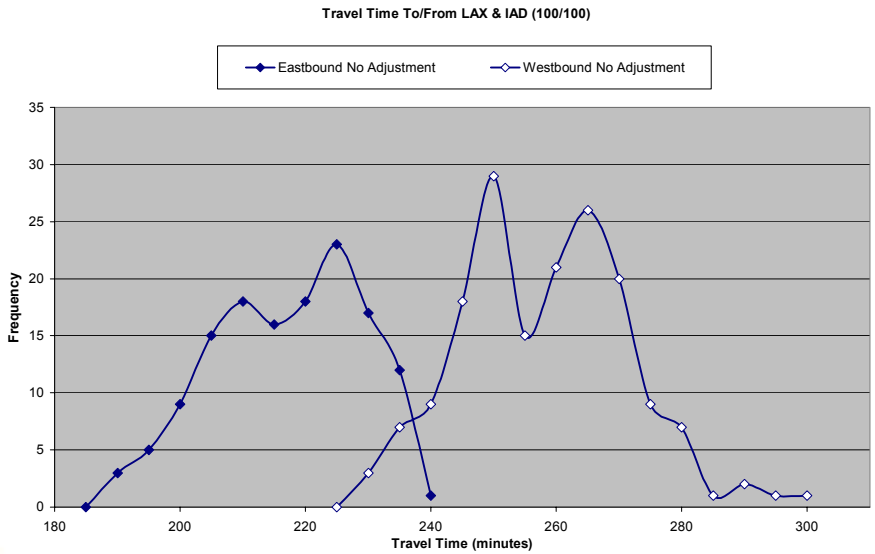
- Using ETMS data, flight times were calculated for each flight along the three segments studied (100, 40, 10 nmi)
  - A flight's origin and destination were accounted for
    - Direction matters: 'A' to 'B' is different from 'B' to 'A'
    - Both airports required to be in the CONUS
  - Aircraft type was also taken into consideration
    - As specified in ETMS
- Actual flight times adjusted for "wind effects" on daily basis
  - Used the "wind effect" adjustments to calculate adjusted flight times: how long it *would have* taken to traverse the flight segment, had the winds not been there
- Flights with "minimum" *adjusted* flight time compared to other flights to determine "excess flight time"
- Analysis performed for different numbers of days
  - Individual days, group of 2…30

Study of Opposing Traffic: Adjusting for Winds

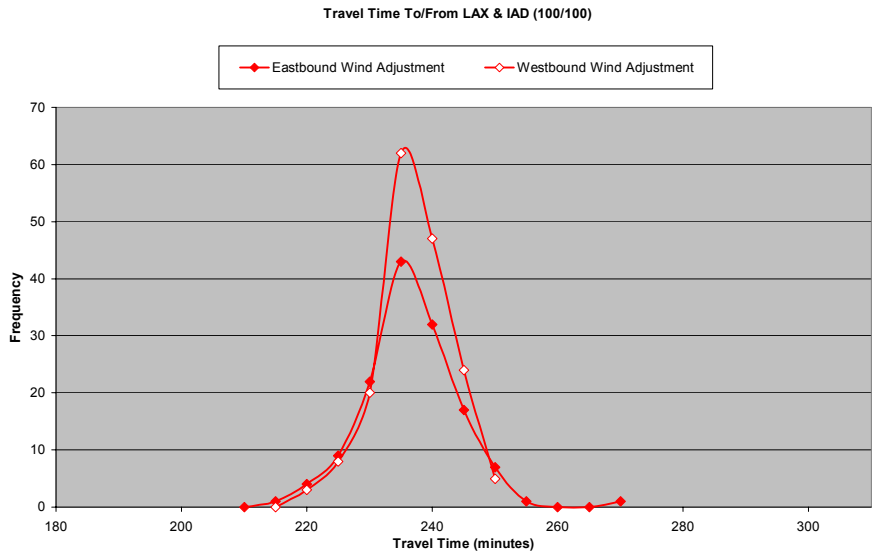
- **Could not simply look at winds aloft data to determine effects of wind along a flight track**
  - **Faced with strong winds, one may decided to counteract by "throttling forward" (head wind) or "back" (tail wind)**
- **Approximated wind effects by looking at opposing traffic**
  - **Calculated *average* speed for flights from A to B and from B to A for the same aircraft type (speed = track distance / time)**
  - **Assumed traffic in both directions would want to travel around the same speed if winds were not a factor**
    - **This assumption picks up other effects besides winds. We tested for this and reported the findings (no impact on analysis)**
  - **Compared average speeds and assumed *half* the difference was the "wind effect"**

Before and After Applying Adjusted Speeds: To and From LAX and IAD

- **In this example, the charts below illustrate the effect of applying the "wind effects" to individual flights on travel time**
  - **X-axis is travel time; Y-axis is number of flights; 30 days of data**
  - **Chart on left illustrates travel time in opposing directions before adjustments made on a *daily* basis**
  - **Chart on right illustrates travel time after accounting for winds**



30 days of data; Number of Flights: 137 flights Eastbound; 169 flights Westbound



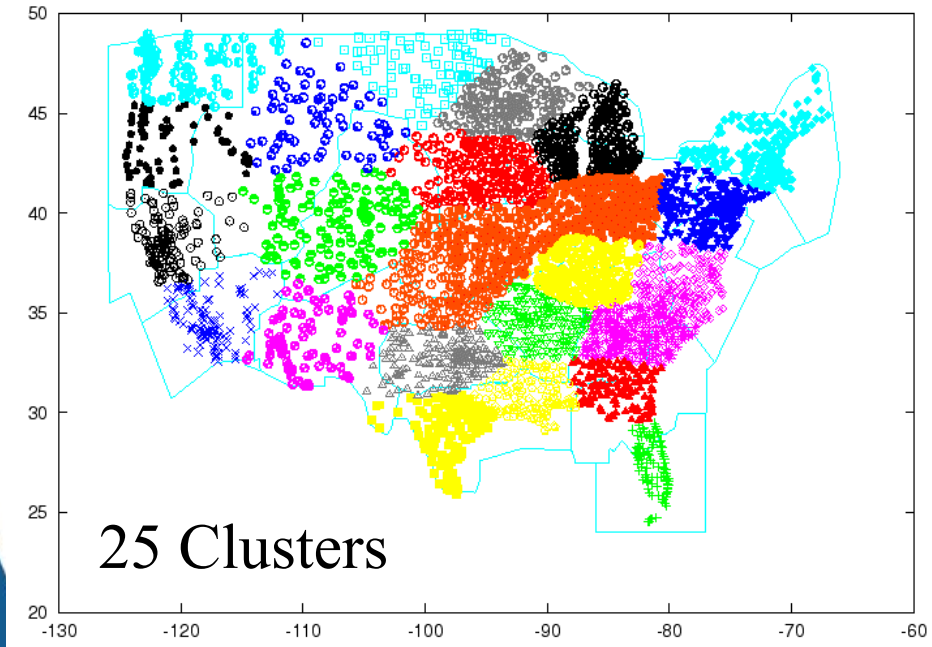
30 days of data; Number of Flights: 137 flights Eastbound; 169 flights Westbound

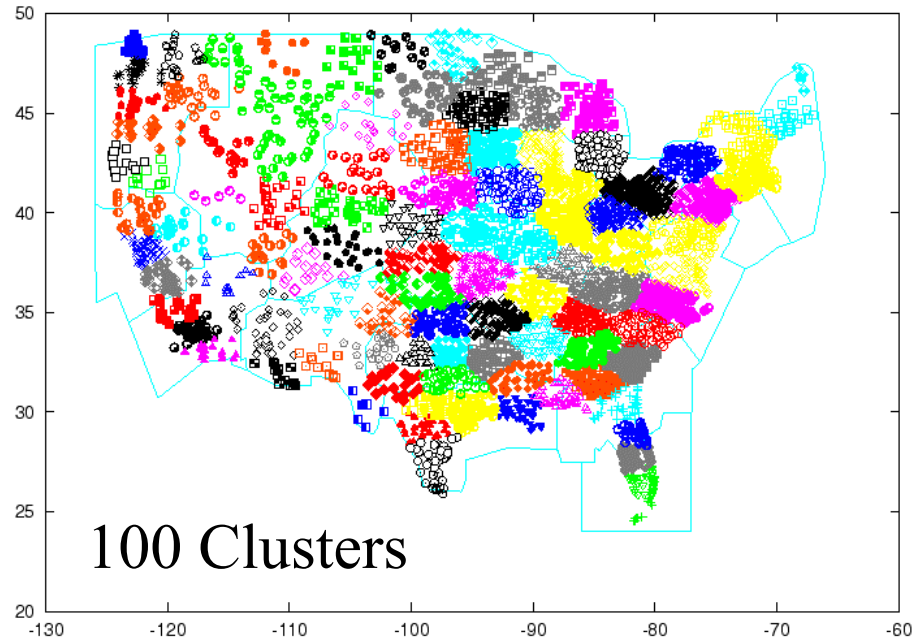
MITRE

CAASD

Grouping 3628 Airports

- **Winds and their effects differ day to day so wind adjustments need to be applied on a *daily* basis**
- **In order to apply the opposing traffic methodology described on the previous pages, adequate traffic needs to exist between the origin and destination pairs**
- **The tradeoff is between the number of flights captured and the "fineness" of wind adjustment applied**

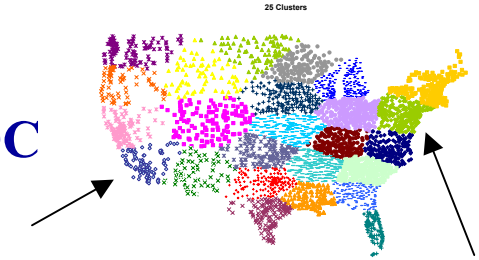


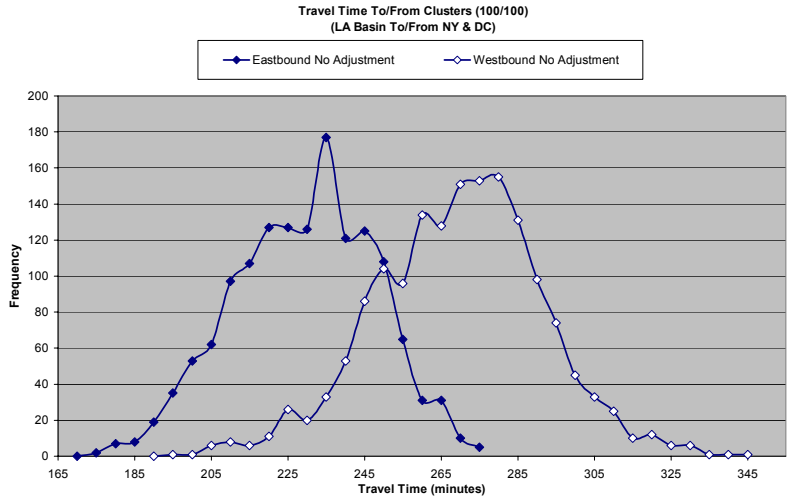


MITRE

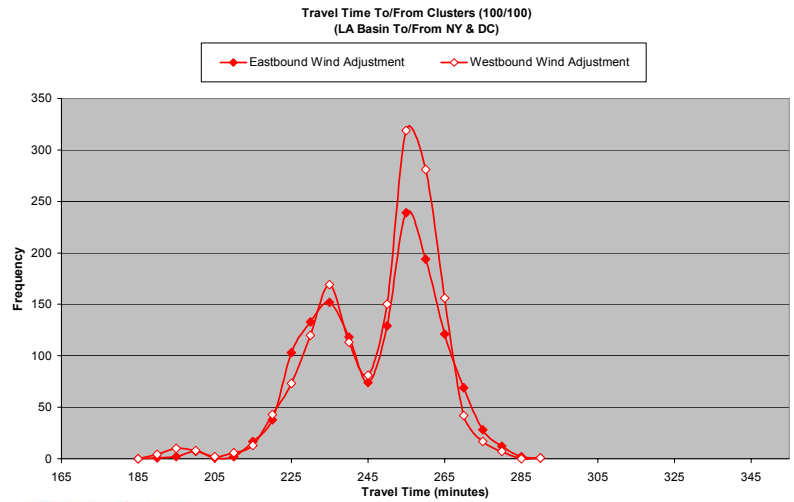
CAASD

Applying Cluster Based Adjustment: Example Wind Adjustments on LA Basin Cluster To/From NY and DC Cluster (100/100 Dataset)



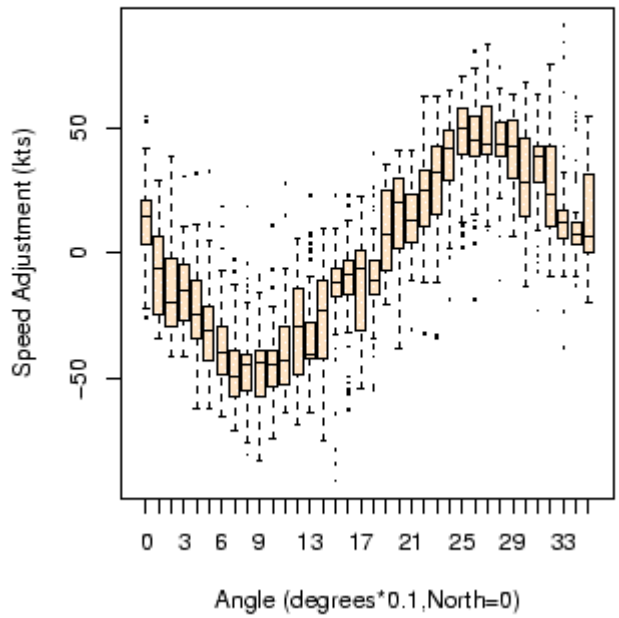


30 days of data; Number of Flights: 1,443 flights Eastbound; 1,615 flights Westbound



30 days of data; Number of Flights: 1,443 flights Eastbound; 1,615 flights Westbound

25 Clusters



MITRE

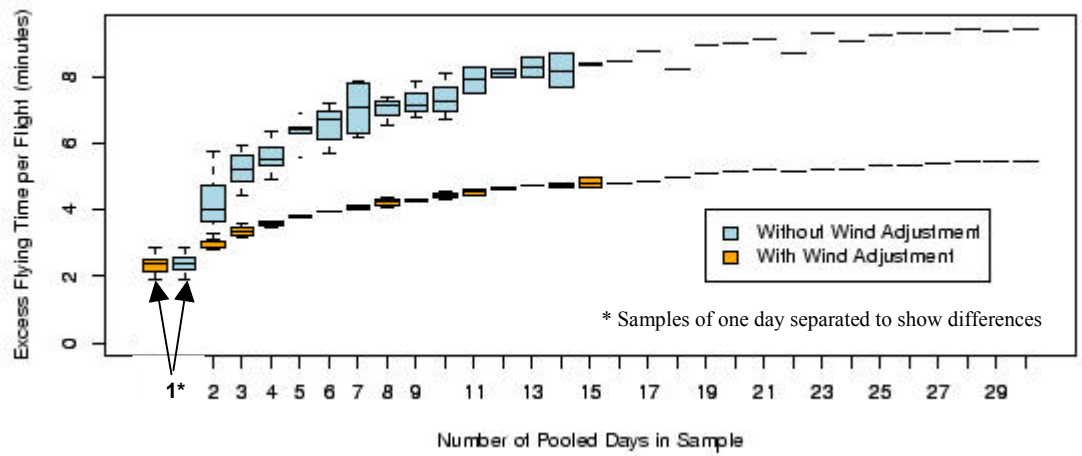
CAASD

Results

NAS-Wide Results: 100/100 Dataset

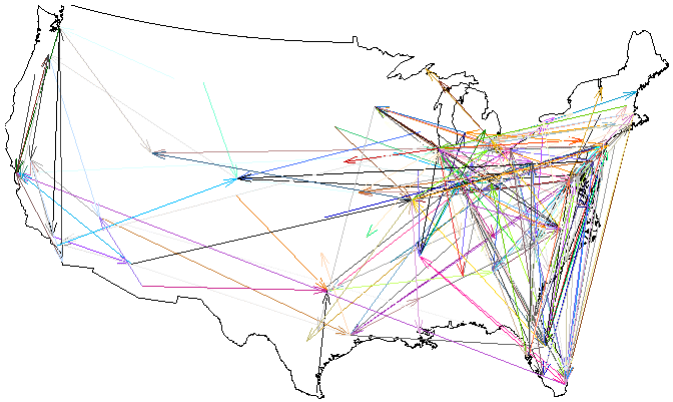
- **Chart below illustrates the average amount of excess flight time (in minutes) for individual days and combinations of days (with and without adjusting for wind)**
  - **When analyzing results on individual days in isolation there is little/no difference between wind adjusted results and unadjusted results**
    - **Probably due to the fact that all flights are impacted by the wind, either positively or negatively, so adjusting does not have a big effect on one particular day**
  - **Adjusting for the winds allows multiple days to be compared and it also reduces the amount of variation in the results (see box plots)**

Excess Flying Time vs. Number of Sampled Days: 100/100 Dataset

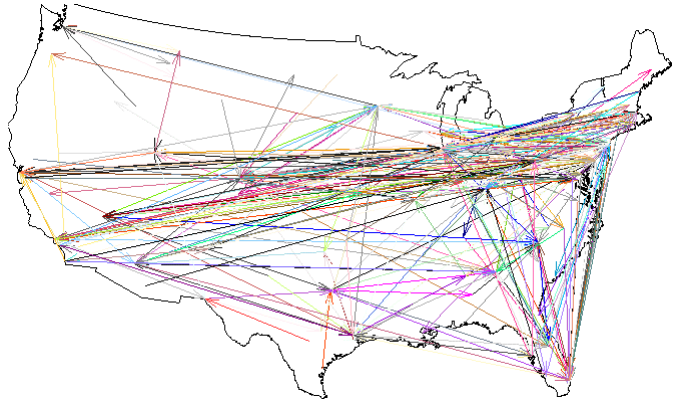


Where Are The Minimums Occurring? Different Parts of the System Perform Best On Different Days

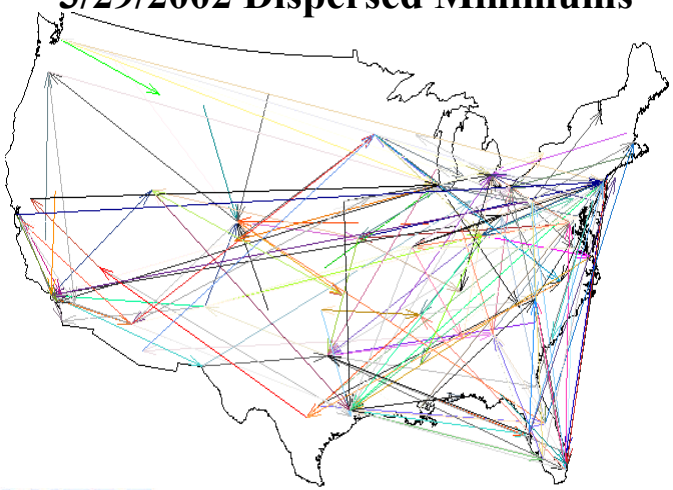
5/8/2001 East Coast Minimums



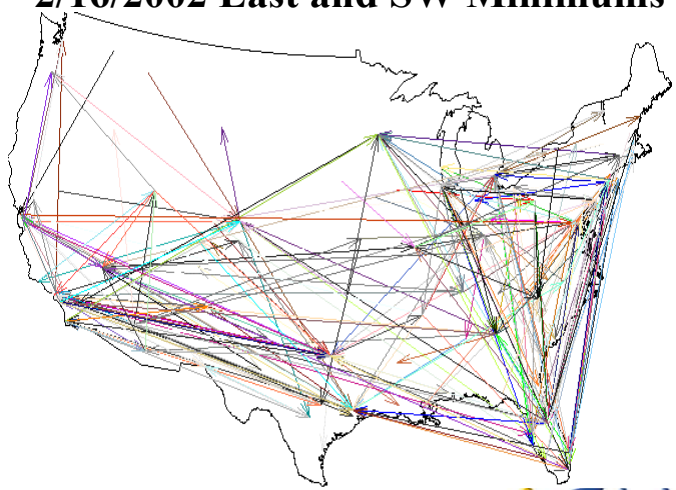
4/22/2002 Trans Con Minimums



3/29/2002 Dispersed Minimums



2/16/2002 East and SW Minimums

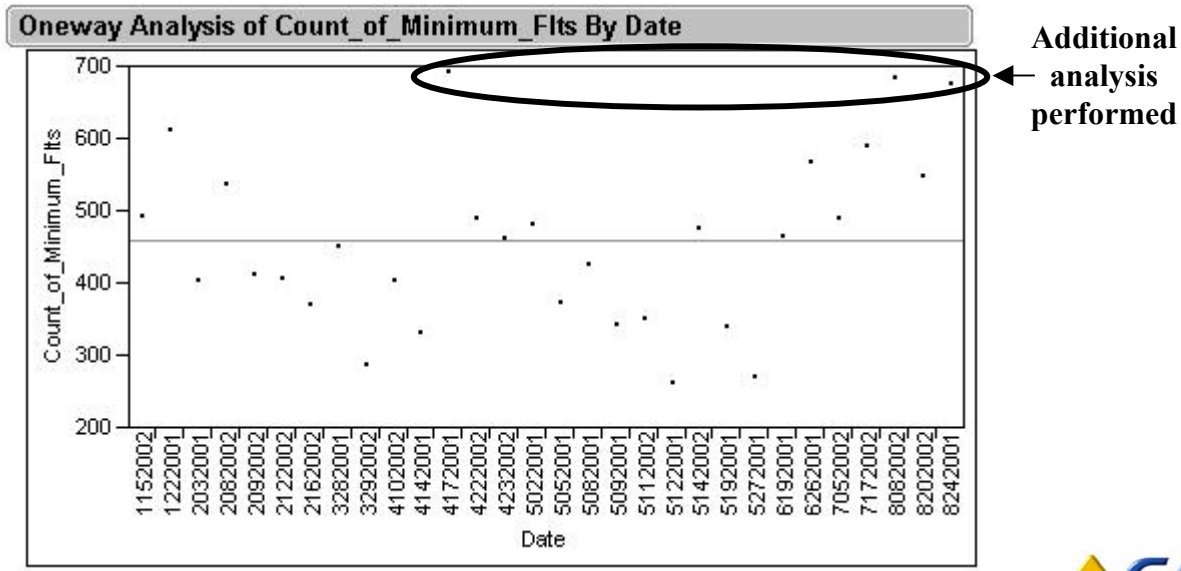


MITRE

CAASD

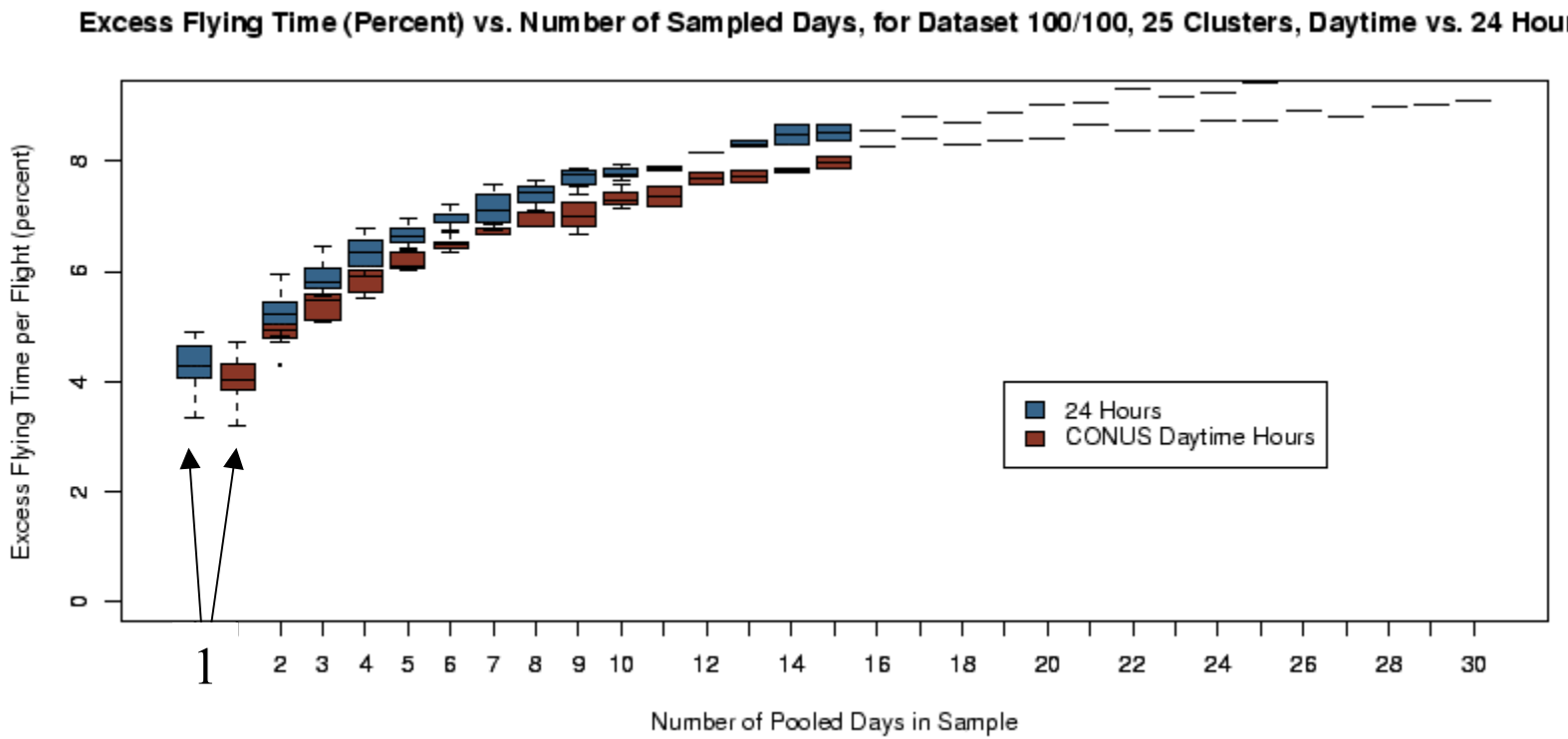
Does Any Particular Day Stand Out Regarding the Number of Minimum Values Obtained on that Day?

- Each day contributed some minimum-time flights to the overall population's pool of minima
- Among our 30 sample days, we searched for days with unusual numbers of minimum-time flights
  - Understating the "true" minimum might over-estimate excess flying time



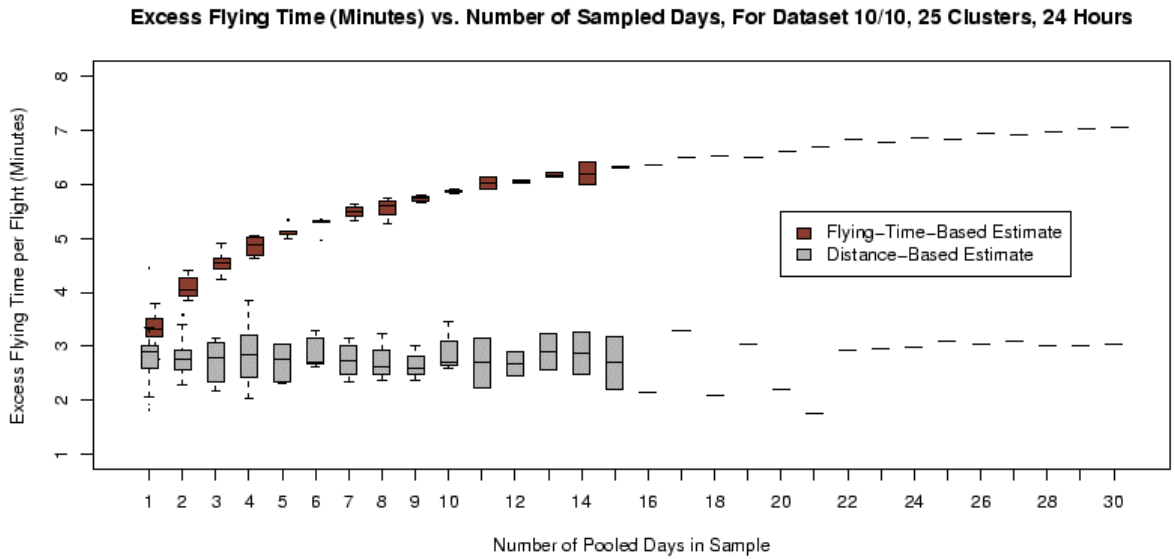
Does Time of Day Matter?

- If many of the minimal flight times were occurring overnight in the non congested hours the pool may appear larger than it really is when congestion is considered
  - Tested for this by comparing 24 hours to Daytime (16 hours)



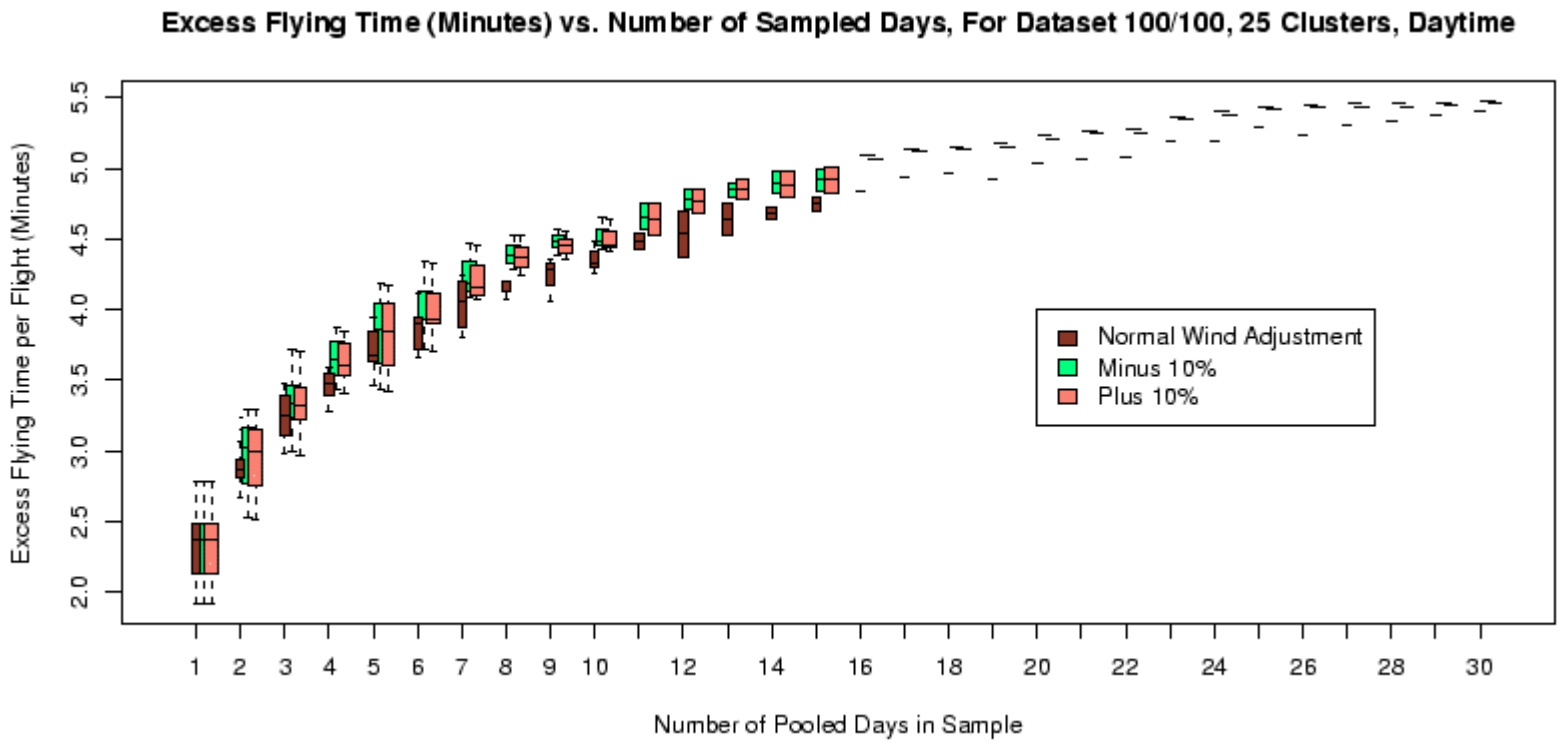
How Do These Results Compare To Distance-Based Results?

- **Methodology**
  - **Calculate great circle distance between 10/10 data points**
  - **Subtract great circle distance from distance flown**
  - **Apply wind adjusted speeds to excess distance**
- **Interpretation**
  - **No increase as additional days are added because each flight has its own minimum (no chance to find lower minimum with additional days)**



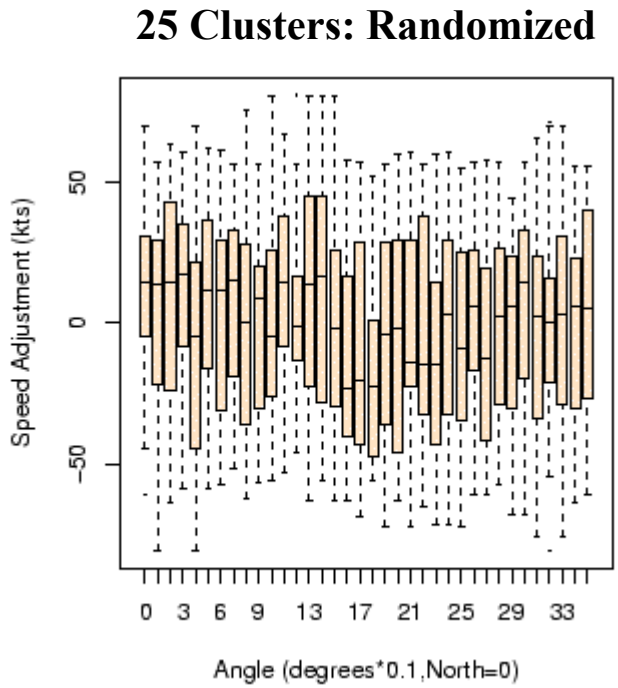
Are We Really Accounting for Winds?

- **Wanted to know how sensitive results are to inaccuracies in wind adjustments**
  - **Tested wind adjustments of +10% and -10%**
  - **Results indicate wind adjustment used minimize excess flying time**



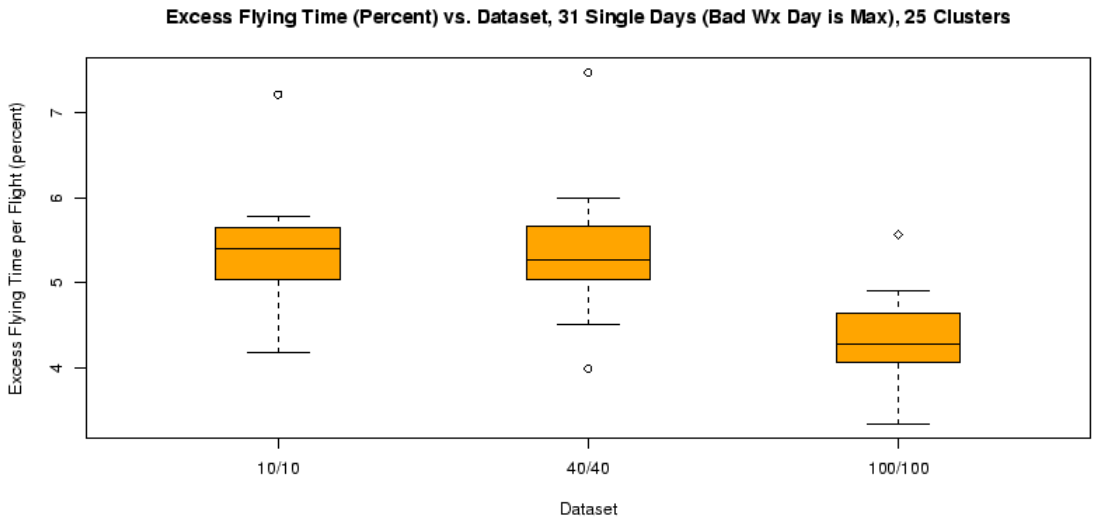
Are We Really Accounting for Winds? Concluded

- Wanted to understand how strongly our results depended on the wind adjustments being made
- As a test we took the wind adjustment data and randomly shuffled it for each day and performed the same analysis as before
  - Chart on right shows effect of randomly shuffling the wind adjustment data
- Results were dramatically different and stable, indicating wind adjustments were performing as expected
  - Wind Adjusted Results: 5.61 minutes; 11.41%
  - Random Analysis Results (3 runs of 40/40 dataset; 30 pooled days): 12.80, 12.87 and 12.86 minutes; 25.42, 25.58, 25.57%



How Different Can the Results Be on a Bad Weather Day?

- We wanted to understand how different our results could be on bad weather days versus the good weather days we analyzed
  - A much more detailed analysis is required (follow on)
  - Only one sample bad weather day was investigated (6/26/02)
- Results indicated large differences in results
  - Excess time based upon 100/100, 40/40, and 10/10 datasets considered "outliers" with larger excesses



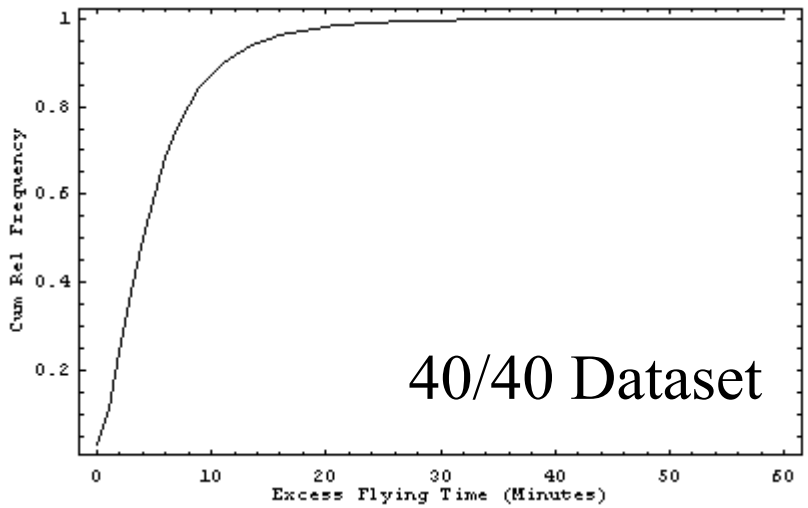
How Representative Are These Results?

- Examination of ETMS data shows that flights into the top 35 benchmark airports represent approximately 66% of the NAS traffic
  - The remaining 34% to go to other airports
- For this analysis the proportion of traffic to/from the top 34 (HNL not included) airports ranges from 93 - 97% (depending on the data set and number of days)
  - Data filters that require a certain number of flights by aircraft type in order to perform calculations limit the sample size
- Therefore, these results represent more of a pool for flights into the major airports
  - Need to prorate to capture all flights (depending on how different the pool is (TBD))
  - Not a large impact: 5.25% (All apts), 5.27% (Top 35), 4.95% (Other Apts)-40/40 dataset, Average of single 1 day sample

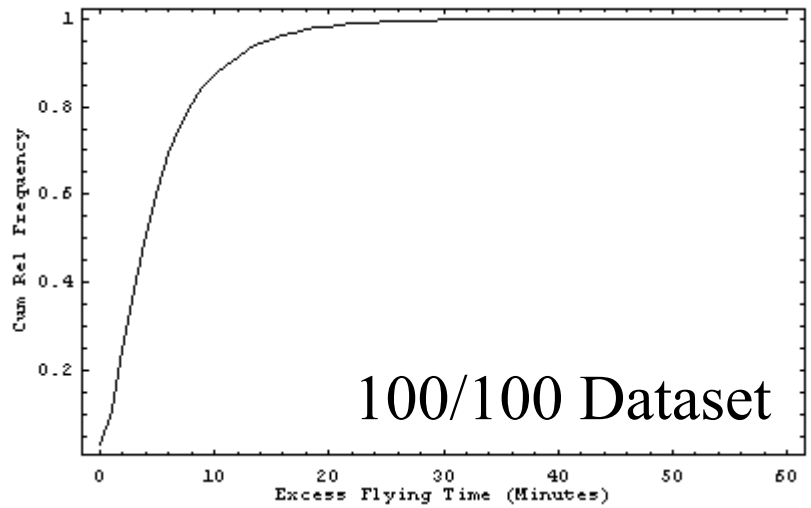
Backup Slides

Why use a Shortest Time and Not a Low Percentile, e.g., Fifth, as the Minimum Value? (40/40 & 100/100 Datasets)

- Based on 335,140 flights & 4,428 combos
- 3% of flights had less than 30 seconds excess flight time; 11% had less than 90 seconds excess flight time
- 38 flights had more than 60 minutes excess flight time



- Based on 218,924 flights & 3,008 combos
- 3% of flights had less than 30 seconds excess flight time; 11% had less than 90 seconds excess flight time
- 14 flights had more than 60 minutes excess flight time

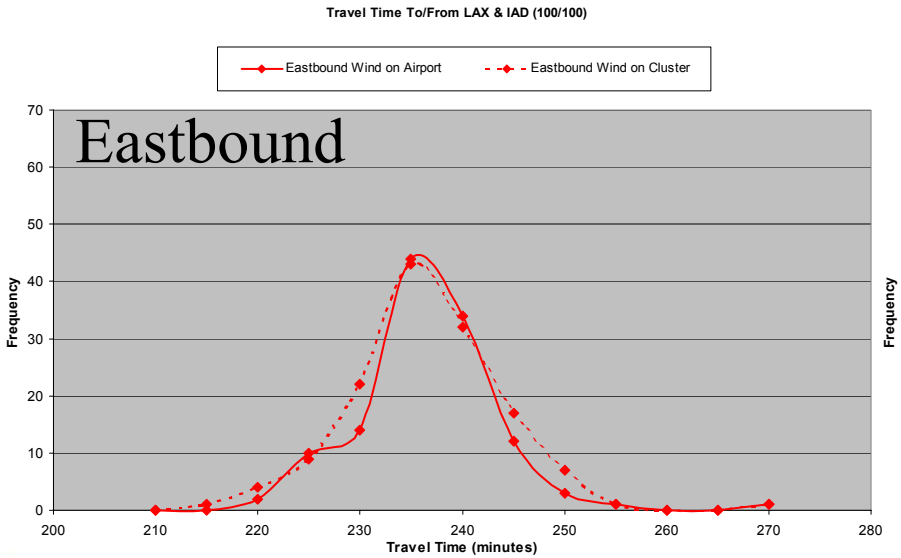


MITRE

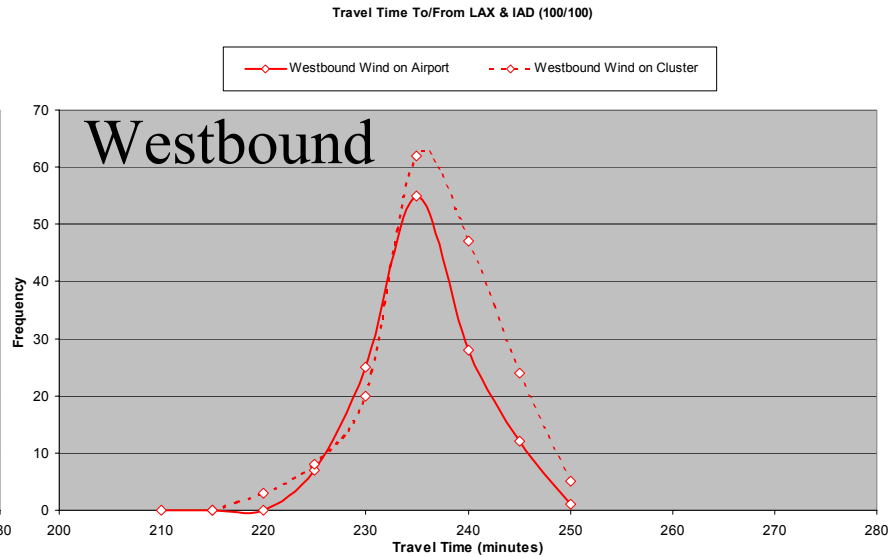
CAASD

With Airport Clustering Are We Really Accounting for Winds?

- **These charts compare wind adjustments performed on clusters versus wind adjustments performed on airports (LAX to IAD)**
  - **Note sample size differences (due to loss of flights when not clustering)**
    - **Eastbound Apt Adjusted: 121 Cluster Adjusted: 137**
    - **Westbound Apt Adjusted: 128 Cluster Adjusted: 169**



30 days of data; Number of Flights: 121 flights Airport Adjusted 137 Cluster Adjusted



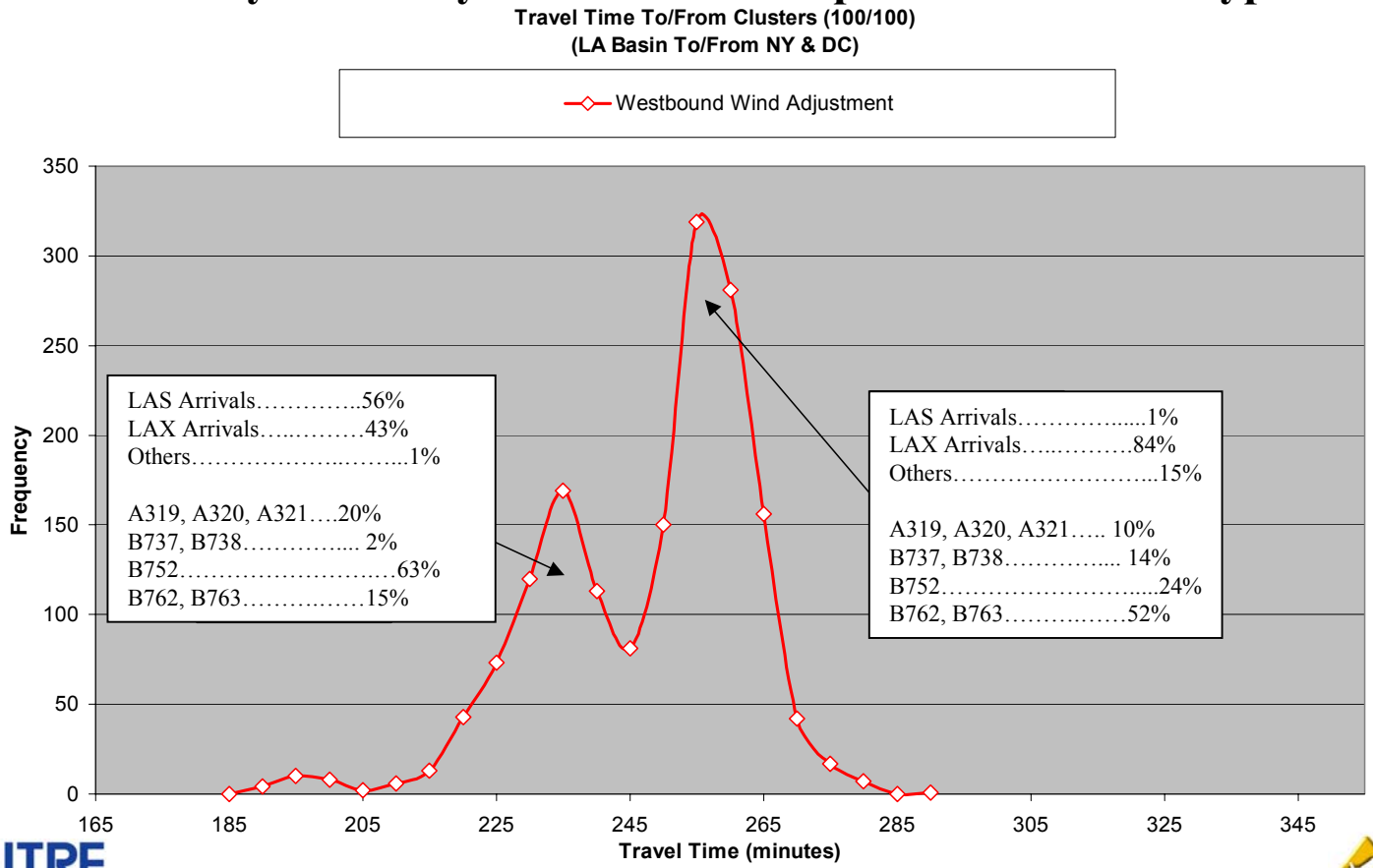
30 days of data; Number of Flights: 128 flights Airport Adjusted 169 Cluster Adjusted

MITRE

CAASD

With Airport Clustering Are We Really Accounting for Winds? Continued

- **Why bi-modal distribution of flight times from LA Basin to NY and DC Clusters?**
  - **Mostly caused by differences in airports and aircraft types**



Number of Flights: 1,615 flights Westbound